

Toward Automatic Swiss Style Rock Depiction

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Abstract. The Swiss style of cartographic rock depiction is a monochrome hachure rendering. In this study, techniques will be presented suitable for automatically deriving such renderings from raster elevation data. These comprise methods for creating terrain models from the raster, serving as a framework for guiding the placement and stylization of the rock hachures. Two modeling approaches will be devised, one (dubbed *contour-net*) using contour lines and the *crust*-algorithm, with the other using 3D Voronoi cells as basic building blocks. Some analysis methods that help in detecting and disambiguating terrain features will be explored: hierarchical DBSCAN clustering, line detection reduced to area classification, ridge-line completion by silhouetting, shape-detection by illumination variation, anisotropic terrain smoothing. Regarding hachure rendering, a technique to imitate hand-drawn strokes will be presented, and the importance of relief shading as the basis for line placement and stylization considered.

Keywords: Terrain analysis, modeling, rock drawing

1. Introduction

The Swiss style of cartographic rock depiction produces monochrome line renderings incorporating shaded relief and aerial perspective effects for enhanced legibility of topography (Imhof 1965) (see fig. 1). Their creation and maintenance is an involved hand-craft requiring drawing skills and expertise in terrain morphology. Thus, automatic methods in support of the rendering process are desirable.

Observing a cartographer manually draw rock depictions reveals, that the actual drawing of lines and hachures is preceded by the implicit construction of an abstract, generalized terrain model. In consequence, (automatic) rock depiction is as much about terrain modeling as it is about hachure rendering. Algorithmic tools for creating Swiss style rock depictions based on raster elevation data will be presented, that build



Figure 1: Rock hachures (Swiss national map 1:25000)

generalized terrain representations from the grid elevations applicable as a reference frame for guiding the placement and stylization of the hachures.

Two modeling approaches will be explored, one using contour lines with the other one using three-dimensional Voronoi cells as basic building blocks.

Concerning the actual rendering of hachure strokes, many techniques already exist that can be utilized (Rusinkiewicz et al. 2008), for cartographic examples see (Hurni 1995, Dahinden 2008).

2. Terrain analysis and modeling

Prior to rendering, a structural representation of the terrain must be available. This (computational) structure is to be derived by analytical means from the given input raster model. Its purpose is to make possible the calculation of all data needed to place the hachure lines.

In this work, several derivatives of the input raster are created and tried for their usefulness concerning cartographic rock depiction. All are based on three inputs: a uniformly gridded 2.5D elevation model, a rockmask (i.e. a raster of the same dimensions as the elevation model) with values „True“ if a cell is mainly composed of rock, „False“ otherwise, and a scale denominator (like „25000“) for the scale of the output map.

The first method starts out from vector contour lines interpolated from the elevation raster by standard tools. The contour lines are simplified by point elimination using a constrained Douglas-Peucker algorithm, i.e. with the option of keeping critical points such as those lying on ridges (e.g. detected in the elevation raster by image processing methods). Another constraint on the points might be proximity to gullies or other skeletal lines. From the resulting point set of all contour line vertices, a Voronoi partition is generated, and the union of the Voronoi-vertices thereof, together with the original contour line vertices, are Delaunay-triangulated. Those edges of the Delaunay triangulation having no endpoint in the Voronoi-vertices belong to the *crust* (Amenta et al. 1998). The crust edges can be combined with the contour lines to build a closed three-dimensional vectorial surface model of the terrain, with the individual faces connecting adjacent isolines (see fig. 2). The model is useful for vectorial modeling of small-scale features as well as extracting large scale skeletal lines, if the contour equidistance and Douglas-Peucker threshold are chosen adequately.

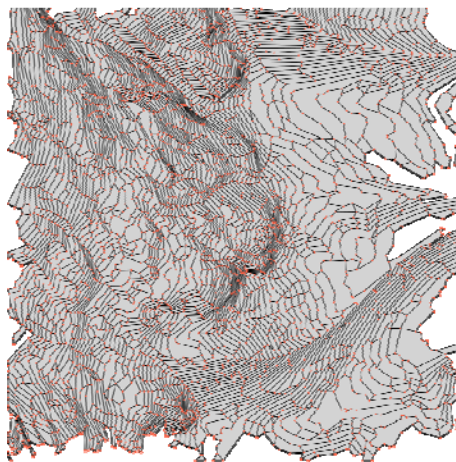


Figure 2: *Crust-based contour mesh*

A complementary approach builds a terrain model by iteratively chopping off half-planes from a parallelepiped enclosing the grid elevations and subdividing at concavities, thus assembling a collection of convex three-

dimensional Voronoi cells. These lend themselves to the creation of rough, sketchy overviews of the prevailing aspect and slope conditions, useful in determining the parameters of the illumination model later on used in the rendering process. Furthermore, the distinctive triangular shapes of rock formations are easily created using the Voronoi cell representation by chopping off planes symmetrically. The representation is very compact: eight vertices for the cuboid (only two if axis-aligned) and one vertex for every half-plane (the plane lies at the midpoint of the line segment from of the cuboid's center to the given vertex, orthogonal to this line). Also, generalization by unifying half-planes is simply achieved by merging adjacent vertices. Since Voronoi cells are convex polytopes, several cells must be assembled if convex topography needs to be modeled. And yet, the assembly of even simple cells can yield complex sceneries (see fig. 3).

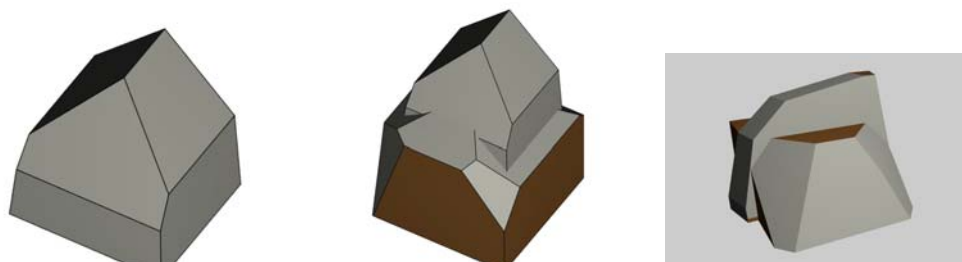


Figure 3: *Single Voronoi cell (left), cell assemblies (center, right)*

Algorithmic modeling involves finding computational analogies to the domain at hand. For instance, the terrain to be modeled is a hierarchy of forms, small features are embedded in larger compounds, ridges and streams compose networks of major and minor branches. Another characteristic is the fractal nature of terrain: resembling structures at different scales. The hierarchical nature of forms will have to be dealt with in the rendering also. That is to say that the rendering style of a local feature must take into account the style of its surroundings, i.e. it should either inherit, share or explicitly contrast the display properties (tone, for example) of its environment.

The computational equivalent to these hierarchical phenomena are tree-structures, sometimes with a designated root node. Especially, clustering techniques can be utilized to produce trees of classifications. One method used was the DBSCAN (Ester et al. 1996) data clustering algorithm. It is straightforward to implement and suitable for nonlinear clustering, i.e. classes don't need to be separated by lines, planes, etc. This requirement is essential for clustering terrain surface properties, where homogeneous

features can bend wildly. The DBSCAN procedure was used to build hierarchies of aspect (see fig. 4) slope and surface normal vector classes by successively tightening the equivalence criterion of the classification attribute. The resulting layers of classifications help in the analysis of terrain features by providing information about area boundaries, and by turning topographical into topological data (i.e. the tree structure) that can be analyzed algebraically (e.g. using graph search) rather than geometrically.

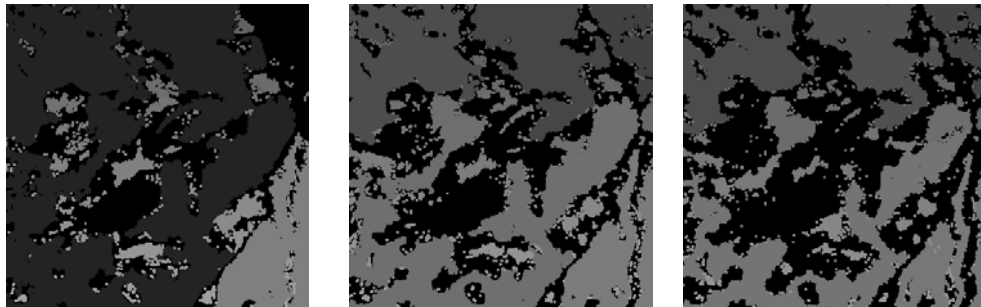


Figure 4: Aspect clustering tree. Imagine the three layers stacked on top of each other, left one is the root.

Having the terrain partitioned into areal features also helps in detecting lineal features, provided these are defined as borders of areas or separations thereof, with the rationale being that lines are more prone to disruption by noise or noisy feature detection methods than the areas clustered with the technique described above. Thus, if a line is expected to exist between two areas, even though if the area borders are corrupted by noise, the line can be taken as the (unique) medial axis separating the areas, e.g. by computing the skeleton (Sonka et al. 2007) and just keeping the shortest path connecting the skeletons extremal endpoints (see fig. 5).

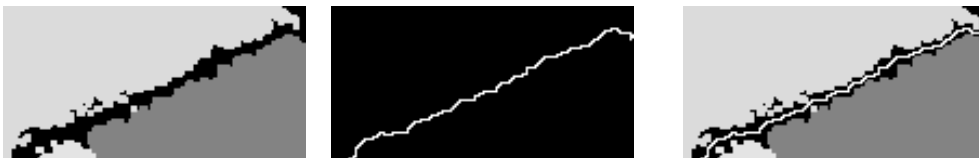


Figure 5: Classified areas separated by noisy line (left), shortest skeleton line between endpoints (center), superposition of left and center (right)

Thus, line detection, common in terrain analysis, is reduced to more robust area detection.

Even with robust line detection methods, one would like a line to be continuous even if the terrain analysis says otherwise. This problem is ubiquitous in generalization, especially for small-scale maps where the cartographer draws virtual lines for the sake of map readability.

Lines can be “completed” by introducing an observer into the scene, resolving the ambiguities of the general map overview by choosing a definite viewpoint and viewing direction. As an example take the ridge line in fig. 6 (left). Near the peak, the crisp line is disrupted by some flattened slopes. Now, if the observer is placed south of this ridge, maybe at the foot of the great southern-exposed mountain face, the silhouette visible from that position makes the ridge a continuous line. The observer-dependent approach to terrain processing is also an essential ingredient of manual rock drawing (Gilgen 2009). Silhouette detection methods abound (Wang et al. 2004).

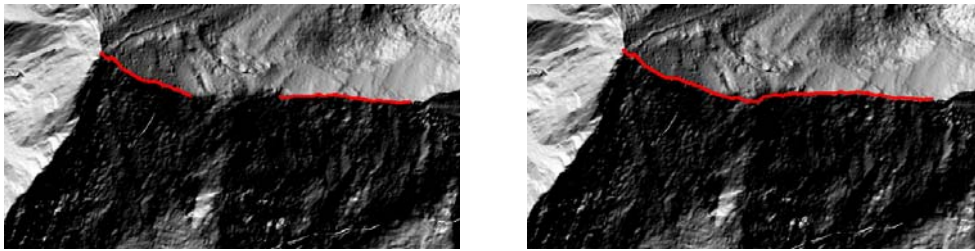


Figure 4: *Discontinuous ridge line (left), continuous ridge line as silhouette*

Another method in the toolbox of directional feature detection concerns the partition of terrain into areas of light, shade and semi-shade. This is actually one of the first steps undertaken by the rock drawing cartographer (Gilgen 2009). A main light direction (azimuth and elevation) is chosen, depending on the major skeletal lines and, using local variations of direction, forms are etched out according to the illumination. The same process, applied dynamically to the scene, can be utilized for detecting important topographic features. In figure 15 the south-face morphology is indiscernible under the given lighting conditions (SE, elevation 45 degrees), but extreme variation of the azimuth (+90 degrees) reveals the distinctive triangular rock shapes (fig. 7).



Figure 5: *Visibility from south east (left), visibility from south west*

All aforementioned procedures were also tried with a smoothed raster. The smoothing algorithm employed is taken from (Tasdizen, Whitaker 2003). The algorithm is a two-step process, smoothing the surface normals using a partial differential equation, and afterwards refitting the original heightmap to the normals. The authors use total curvature as the measure for guiding the smoothing process: where curvature is low, surface normals will be aligned to ultimately form planes, whereas in regions of high curvature (e.g. ridge lines or cliff edges) normals are left unaltered (see Appendix). One could easily extend the curvature signal to include further constraints for smoothing, for example by setting high curvature values along lines (like flow lines, gullies) one wants to be preserved.

3. Rendering

We want the graphic output, monochrome hachure lines, to resemble manually drawn rock depiction, so properties like stroke wobbline and density should be imitated from existing maps. Therefore, stroke samples were taken from the 1:25000 Swiss national (raster) map (fig. 8), vectorized, and the deviations of the vertices from ideal lines statistically evaluated. The resulting empirical distribution can in turn be used for generating strokes similar to the samples of the national map.



Figure 6: Hachure samples taken from Swiss national map 1:25000 (left), deviations of sample stroke vertices from ideal line (right)

Relief shading, albeit a relief presentation method of its own, will be used during hachure rendering as an underlying lookup matrix for determining stroke width and the mean distance between strokes. Both parameters, width and distance, as well as the absence of strokes, another design element in rock depiction as important as the strokes themselves, make up for the distribution of light and shade on the map. Together with the stroke directions, these properties alone must account for the interpretation of terrain forms by the map reader. Standard oblique analytic hillshading

(single light azimuth and elevation) is not useful in this case. Rather, techniques from manual cartographic relief shading should be employed like locally varying the light incidence in order to gain contrast along ridges parallel to the main lighting direction, and using a method analogous to aerial perspective i.e. a crispness as well as contrast gradient from valleys (fuzzy) to peaks (high contrast). The latter can be implemented as a lookup matrix (just another shading), i.e. a value for each pixel indicating its distance from a designated ridgeline.

The terrain smoothing procedure described above greatly helps in calculating a shading smooth in level regions and constant slopes, but crisp at ridges and other important lines.

4. Conclusion

Several techniques of terrain analysis have been considered. That leaves the task of combining these into a unifying model powerful enough to derive Swiss style inspired rock depictions. What has not been considered yet is the relation of the scale denominator of the output map to the parameters of all presented methods (for example the curvature parameter in the terrain smoothing method). Parameters should depend on that scale denominator and should be meaningful to the user, i.e. have reasonable interpretations. Modes of depiction other than traditional manual methods should be tried, also.

5. References

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6. Appendix

Hillshading of “Weisshorn” raster elevation model and smoothed raster (below).

